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1 **Abstract**

2 **Purpose:** To examine the influence of knowledge of exercise duration on pacing and
3 performance during simulated rugby league match-play. **Methods:** Thirteen male university
4 rugby players completed three simulated rugby league matches (RLMSP-i) on separate days
5 in a random order. In a control trial, participants were informed that they would be
6 performing 2 x 23 min bouts (separated by 20 min) of the RLMSP-i (CON). In a second trial,
7 participants were informed that they would be performing 1 x 23 min bout of the protocol,
8 but were then asked to perform another 23 min bout (DEC). In a third trial, participants were
9 not informed of the exercise duration and performed 2 x 23 min bouts (UN). **Results:**
10 Distance covered and high intensity running was higher in CON (4813 ± 167 m; 26 ± 4.1
11 $\text{m} \cdot \text{min}^{-1}$) than DEC (4764 ± 112 m; $25.2 \pm 2.8 \text{ m} \cdot \text{min}^{-1}$) and UN (4744 ± 131 m; $24.4 \text{ m} \cdot \text{min}^{-1}$).
12 ¹). Compared to CON, high intensity running and peak speed was typically higher for DEC in
13 bout 1 and lower in bout 2 of the RLMSP-i, whilst UN was generally lower throughout.
14 Similarly, DEC resulted in an increased heart rate, blood lactate and rating of perceived
15 exertion than CON in bout 1, whereas these variables were lower throughout the protocol in
16 UN. **Conclusions:** Pacing and performance during simulated rugby league match-play is
17 dependent on an accurate understanding of the exercise end-point. Applied practitioners
18 should consider informing players of their likely exercise duration to maximise running.

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20 **Key Words:** Deception. Team Sports. Fatigue. Rating of Perceived Exertion.

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26 Introduction

27 Pacing, defined as the distribution of energy expenditure during athletic competition, has
28 been well-defined in continuous 'closed-loop' exercise¹. Indeed, an athlete's pacing strategy
29 is fundamental to success in events where maintaining the highest average speed is the goal².
30 However, in team sports that comprise different actions such as standing, walking, jogging,
31 sprinting and tackling, pacing is less well understood.

32

33 In rugby league, the amount and type of work that athletes complete appears to be related to
34 playing position³, playing standard⁴, nature of the opposition⁵, playing home or away⁵ and
35 whether the player is playing for the whole match or part of it⁶. Furthermore, running
36 intensity fluctuates during a match more stochastically than 'continuous' exercise⁷, but in a
37 predictable enough manner such that common traits are apparent. That is, there is often a
38 gradual reduction in total and high-intensity running over the course of a game, and a period
39 of repeated high-intensity efforts is followed by a transient reduction in energy expenditure
40 relative to the match average⁸.

41

42 Accordingly, it appears that several different variables influence an athlete's movement
43 characteristics such that they 'pace' their efforts during exercise. However, the precise way in
44 which athletes do this is unclear. During continuous exercise, it is thought that athletes
45 regulate their exercise in accordance with the principle of teleoanticipation⁹, whereby work is
46 distributed based on a complex interplay between a feed-forward template developed for the
47 exercise and feedback from peripheral and central physiological systems. For this model of
48 exercise regulation, the athlete must know the exercise duration to adopt an appropriate
49 pacing strategy that enables safe completion^{10,11}. Interestingly, deception of the exercise end-

50 point affects performance during both continuous exercise¹² and repeated sprints¹³, such that
51 more work is completed in the early stages of exercise.

52

53 However, only one study has examined this phenomenon when athletes are required to
54 perform intermittent activity specific to team sports. Gabbett et al.¹⁴ reported that players
55 covered greater distance during a 12-minute small-sided game when they were deceived
56 about the exercise duration (130.6 m·min⁻¹) rather than informed of it accurately (123.3
57 m·min⁻¹), whilst they also performed ~2 m·min⁻¹ more high-intensity running in the initial 6
58 min of the game. Thus, an athlete's pacing strategy is seemingly influenced by a manipulated
59 understanding of exercise duration in stochastic and intermittent sports. However, Gabbett
60 and colleagues' use of short duration training activities limits the extrapolation of their
61 findings to match play, given that an individual's pacing strategy is clearly influenced by
62 exercise duration¹. Furthermore, match play includes physical contacts and collisions, which
63 are known to add a significant physiological cost to exercise¹⁵, and influence work done via
64 running¹⁶. Finally, Gabbett et al.¹⁴ did not include any physiological measurements, thus
65 mechanistic insight on changes in running during teams sports are limited. As such, whilst
66 this work provided valuable information on pacing during training, it remains unclear
67 whether an individual's understanding of exercise duration influences work during activity
68 more closely aligned to the demands of rugby. Accordingly, the aim of this study was to
69 examine the influence of knowledge of exercise duration on pacing strategy and
70 physiological responses during simulated rugby league match play.

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75 **Methods**

76 Participants

77 After approval from the Faculty of Life Sciences Research Ethics Committee, 13 male
78 university standard rugby players volunteered to participate in the study (age = 22 ± 3 years,
79 stature = 1.77 ± 0.02 m, body mass = 82.7 ± 8.0 kg, predicted $\dot{V}O_{2\max} = 54 \pm 4$ ml·kg⁻¹·min⁻¹).
80 ¹). All participants provided written informed consent and completed a health questionnaire
81 before starting the study. Participants engaged in rugby related training for approximately 4
82 hours and participated in one competitive match per week.

83

84 Design

85 Participants completed four visits in a repeated measures design. On the initial visit,
86 participants completed a multi-stage fitness test¹⁷ before familiarisation with an isokinetic
87 dynamometer and the rugby league movement simulation protocol (RLMSP-i). In the
88 following three visits, in a random order, participants completed the same RLMSP-i where
89 they were: a) accurately informed of the exercise duration (CON); b) deceived of the exercise
90 duration (DEC); c) not told how long the exercise duration would be (UN). Each visit was
91 separated by seven days and performed at the same time of day. Participants were instructed
92 to refrain from strenuous exercise in the 48 h before each trial, and completed a food diary in
93 the 48 h before the first visit, which they were then asked to replicate before subsequent
94 trials.

95

96 Methodology

97 On an artificial 3G playing surface, participants completed the RLMSP-i, which accurately
98 replicates the average speed, distance and playing time of elite interchange rugby league
99 players¹⁸. Before the protocol, participants performed a 10 min standardised warm-up

100 consisting of varied running intensities and dynamic stretches. Environmental conditions
101 were recorded for each trial. CON, DEC and UN were performed at a similar temperature
102 ($25.1^{\circ}\text{C} \pm 4.7^{\circ}\text{C}$, $24.1^{\circ}\text{C} \pm 2.4^{\circ}\text{C}$, $22.6^{\circ}\text{C} \pm 2.9^{\circ}\text{C}$) and relative humidity ($32.2\% \pm 10\%$,
103 $30.3\% \pm 7.1\%$, $33.8\% \pm 7.9\%$).

104

105 The simulation protocol consists of 2 x 23 min bouts of intermittent exercise separated by 20
106 min. Running alone, participants were instructed to perform various activities in time with an
107 audio signal from a CD, with distances demarcated by cones positioned on a 28.5 m track,
108 details for which have been described in detail elsewhere¹⁸. Before the protocol, participants
109 were given standardised instructions that were specific to each trial. Briefly, in CON,
110 participants were instructed that they would be performing 2 x 23 min exercise bouts. In
111 DEC, participants were told that they would be performing 1 x 23 min bout, but upon
112 completion of this bout were asked to complete a further 23 min. In UN, participants were
113 told that they would be exercising for an unknown period of time up to 80 min, but again
114 performed 2 x 23 min bouts. Thus, participants completed the same exercise protocol in each
115 trial, but received different instructions on the exercise duration. In each trial a clock was
116 made visible to the participants to gauge the duration of the exercise bout.

117

118 During the protocol, movement speeds and heart rate (HR) were recorded using a global
119 positioning system (GPS) positioned in a custom made vest positioned between the
120 participant's scapulae (MinimaxX S5, firmware 6.75, Catapult Innovations, Melbourne,
121 Australia). Total distance, high-intensity running ($> 14 \text{ km}\cdot\text{h}^{-1}$) sprint speed and average HR
122 were calculated and analysed per quartile of each 23 min exercise bout ($\sim 5.75 \text{ min}$). These
123 variables possess adequate reliability to detect a meaningful change in performance ($\text{CV}\% =$
124 $1.1\text{-}2.9\%$ ¹⁸). Satellite availability during experimental trials was 12-19. A rating of perceived

125 exertion (RPE) was provided at the end of each quartile, while blood lactate was recorded
126 from a fingertip capillary blood sample (Lactate Pro, Arkray, Kyoto, Japan) ~ 5 min before
127 the protocol and immediately after each 23 min bout. Peak isokinetic knee extension torque at
128 $60 \text{ deg}\cdot\text{s}^{-1}$ (Biodex Multi-Joint Sytem 3, Biodex Medical, USA) was also recorded ~ 1 h
129 before and ~ 30 min after exercise, with the peak value from five repetitions of the dominant
130 limb taken for analysis. Participants were restrained to minimise any extraneous movement,
131 with the dynamometer lever arm positioned at the participants' malleoli. The mass of the
132 limb was recorded to allow for gravitational correction of recorded torque, and participants
133 received visual feedback of their torque production to encourage maximal effort.

134

135 Statistical analysis

136 All data are presented as mean \pm standard deviation (SD). Changes in movement,
137 physiological and perceptual responses to the RLMSP-i were analysed using qualitative
138 inferences based on effect sizes and associated 90% confidence intervals¹⁹. Effects were
139 classified as small (mean difference greater than $0.3 \times$ pooled SD), moderate ($0.9 \times$ pooled
140 SD) or large ($1.6 \times$ pooled SD), with the following thresholds for likelihood based on
141 confidence intervals; $<0.5\%$ most unlikely, $0.5\text{-}5\%$ very unlikely, $5\text{-}25\%$ unlikely, $25\text{-}75\%$
142 possibly, $75\text{-}95\%$ likely, $95\text{-}99.5\%$ very likely, $>99.5\%$ most likely. Statements based on the
143 size and likelihood of an observed effect are made in italics for clarity, whilst differences are
144 presented as the change; $\pm 90\%$ confidence interval.

145

146 Results

147 Movement characteristics during the RMPSP-i

148 From the first to the second exercise bout, there was a *most likely moderate* decline in
149 distance covered in CON ($-2.6; \pm 1 \text{ m}\cdot\text{min}^{-1}$), with a *most likely large* and *very large* decline

150 in UN ($-3.8; \pm 1.3 \text{ m}\cdot\text{min}^{-1}$) and DEC ($-4.0; \pm 1.4 \text{ m}\cdot\text{min}^{-1}$), respectively. For high intensity
151 running, there was a *most likely small, moderate, and large* decline between bouts for CON ($-$
152 $2.5; \pm 0.7 \text{ m}\cdot\text{min}^{-1}$), UN ($-2.7; \pm 1.1 \text{ m}\cdot\text{min}^{-1}$) and DEC ($-3.4; \pm 1.1 \text{ m}\cdot\text{min}^{-1}$), respectively.

153

154 There was a *possible small* decrease in the total distance covered in the RLMSP-i during the
155 DEC trial compared to CON ($-49.1; \pm 56.9 \text{ m}$), but no difference between CON and UN or
156 DEC and UN (Figure 1a). However, for high intensity running, the difference between CON
157 and UN was *possibly moderate* ($-1.6; \pm 2.0 \text{ m}\cdot\text{min}^{-1}$), and *possibly small* ($-0.8; \pm 1.2 \text{ m}\cdot\text{min}^{-1}$)
158 between CON and DEC and DEC and UN, respectively (Figure 1).

159

160 *****Insert Figure 1 about here*****

161

162 Specific meaningful differences in pacing during the RLMSP-i are shown in Figure 2. Most
163 notably, DEC resulted in participants covering a *moderately lower* ($-3.4; \pm 2.2 \text{ m}\cdot\text{min}^{-1}$)
164 distance in the initial quartile of the second bout of exercise, and generally less high intensity
165 running over the second bout (but most notably in the final quartile). In the UN trial, there
166 was a general *small* decline in distance covered and high intensity running compared to CON
167 in each quartile, with a larger difference observed in the final quartile of the protocol ($-3.2; \pm$
168 $2.6 \text{ m}\cdot\text{min}^{-1}$). The peak speed that participants achieved in each quartile was *possibly higher*
169 in DEC for bout 1, but lower for bout 2, particularly in the final quartile ($-1.3; \pm 1 \text{ km}\cdot\text{h}^{-1}$).
170 Much like HIR, UN resulted in a *possible* reduction in peak speed across quartiles, but
171 especially in the final quartile of the protocol ($-1.8; \pm 1.1 \text{ km}\cdot\text{h}^{-1}$).

172

173 *****Insert Figure 2 about here*****

174

175
176 Physiological and perceptual responses
177 Heart rate and RPE was *possibly* higher in in the final quartile of bout 1 in DEC compared to
178 CON ($3.8; \pm 5.8 \text{ b} \cdot \text{min}^{-1}$). In UN, heart rate was *possibly* lower than CON in the final quartile
179 of bout 2 ($-4.1; \pm 7.4 \text{ b} \cdot \text{min}^{-1}$), whilst RPE was *likely* lower for most of the quartiles of the
180 RLMSP-i. At the end of bout 1, blood lactate concentration was *possibly* higher in DEC
181 compared to CON ($1; \pm 1 \text{ mmol} \cdot \text{l}^{-1}$), and lower in UN compared to CON ($1.8; \pm 1.4 \text{ mmol} \cdot \text{l}^{-1}$).
182 At the end of bout 2, there was a *likely moderately* higher blood lactate concentration in CON
183 compared to UN and DEC (Table 1). *Small* decrements in isokinetic peak torque of the knee
184 extensors after the RLMSP-i were apparent in the CON and DEC trials only (Table 2).

185

186 *****Insert Tables 1 and 2 about here*****

187

188 Discussion

189 This is the first study to examine the influence of knowledge of the task end-point on pacing
190 during exercise designed to simulate the match demands of a contact team sport. Our data
191 indicate that an individual's understanding of the exercise duration is a key determinant of
192 pacing strategy and performance during this type of exercise. Specifically, participants
193 appeared to cover the greatest distance and perform more high intensity running when they
194 were correctly informed of their exercise duration, whilst the opposite was true when
195 participants were unaware of the exercise duration. With regard to the pacing strategy
196 adopted during the RLMSP-i, participants covered less distance, performed less high
197 intensity running and attained a lower peak sprint speed in most bout quartiles compared to
198 when they were correctly informed of the exercise duration. Contemporaneous changes in the

199 physiological and perceptual responses to movement tended to reflect the change in external
200 load observed in each condition.

201

202 The general reduction in exercise intensity in UN was also associated with a reduced RPE
203 and blood lactate concentration throughout the RLMSP-i compared to CON. Our observation
204 that individuals voluntarily lower their exercise intensity and physiological exertion when
205 they are unaware of the exercise duration is consistent with previous research in continuous²⁰
206 and repeated-sprint exercise¹³. This down regulation of pacing strategy is thought to be the
207 consequence of participants maintaining a metabolic reserve to reach the unknown exercise
208 end-point without premature exhaustion or severe disturbance to homeostasis²¹. According to
209 contemporary pacing theories^{9,10,11,22,23}, individuals are thought to undertake exercise with a
210 pre-set template of their exercise intensity, which is a function of their understanding of the
211 exercise duration and previous experience. However, during exercise this template undergoes
212 dynamic alterations based on feedback to the central nervous system from peripheral
213 structures regarding the amount of homeostatic disturbance²⁴. The sum of these afferent
214 signals is thought to be reflected in an individual's RPE, which can then be continually
215 compared to the 'template' RPE set before exercise¹¹. As such, it is unsurprising that
216 participants adopted a lower RPE – and indeed attained an average RPE of only 14 at the end
217 of the RLMSP-i - in the face of an unknown exercise duration in the present study. We
218 propose that this would ensure a sufficient metabolic reserve was maintained to complete
219 upcoming unknown events with minimal risk of a severe disturbance to homeostasis. Indeed,
220 that participants' isokinetic muscle function remained unchanged after completing the
221 RLMSP-i in the UN condition indicates minimal fatigue was present. This seemingly resulted
222 in a sub-optimal performance given that participants completed 1.4% less distance, 6.2% less

223 high-intensity running, and produced a maximal sprint that was 4.8% lower than when they
224 were correctly informed of the exercise duration.

225

226 Further evidence that participants maintained a significant metabolic reserve in the UN trial is
227 the lack of an end-spurt. That is, participants failed to increase their running speed towards
228 the end of the protocol, as is commonly observed during several types of self-paced
229 exercise²⁵. An end-spurt results from a reduced uncertainty of the remaining exercise
230 duration, and thus no metabolic reserve needs to be maintained and motor unit recruitment
231 and RPE increases with a reduced threat of homeostatic failure¹¹. This relationship between
232 exercise intensity, RPE and remaining exercise time has been described using a ‘hazard
233 score’, which is the product of remaining exercise duration and momentary RPE²⁶. Whilst in
234 events of known duration individuals are willing to increase exercise intensity when the end-
235 point approaches (as the hazard score will be low), it seems that when participants are
236 unaware of the exercise duration during simulated team sport exercise, the possibility of an
237 extended exercise duration results in a hazard score which cannot be calculated and thus an
238 end-spurt does not occur.

239

240 Interestingly, an end-spurt was evident in the CON and DEC trials, but this occurred at
241 different times. That is, participants increased their peak speed in the final quartile of bout 1
242 in DEC (the time they believed the protocol would finish), whereas this occurred at the end of
243 bout 2 in CON. Participants seemed to increase their exercise intensity across bout 1 in DEC
244 compared to CON, whilst this condition produced the highest peak sprint speed of all trials.
245 However, much like UN, deception of the exercise end-point seemed to result in a pacing
246 strategy that was sub-optimal across the two exercise bouts of the RLMSP-i, as peak speed

247 was reduced in bout 2, and participants completed 1.1% and 4% less distance covered and
248 high-intensity running, respectively.

249

250 Whilst our findings are consistent with others who have examined knowledge of the exercise
251 end-point on endurance^{20,25,27}, repeated-sprint performance¹³ and repeated maximal voluntary
252 contractions²⁸, they are different to the only study to investigate the effect of knowledge of
253 task end-point in team sport athletes. Gabbett et al.¹⁴ reported that rugby players covered a
254 greater total distance and high intensity running during small-sided games when they were
255 deceived compared to when the duration of exercise was known. Participants also increased
256 relative distance during the unknown compared to known condition, although the unknown
257 condition comprised more low intensity activity. The reason for the discrepant findings of
258 Gabbett et al.¹⁴ are not clear, although it was proposed that their participants were likely to
259 have a prior knowledge of the usual duration of training games, and thus an ‘unknown’ and
260 ‘deception’ trial might have had limited influence on participants’ pacing strategy.
261 Furthermore, the shorted exercise duration (~6-12 min) employed by Gabbett et al.¹⁴ might
262 have encouraged a different pacing strategy to that observed in the present study. Indeed,
263 shorted exercise durations are typically associated with an ‘all-out’ pacing strategy¹, rather
264 than the even pacing observed here.

265

266 Practical Applications

267 For the first time we provide evidence that contact team sport players regulate their
268 movement activity based on an understanding of the match end-point, adopting a pacing
269 strategy similar to other forms of closed-looped exercise. We believe this has potential
270 applied implications for team sports athletes. Most importantly, to maximise running, team
271 sport players who have the potential to be interchanged should be informed of their likely

272 exercise duration. This might include telling an interchange player how long their bout will
273 be (or indeed how many bouts they are likely to be involved with) or accurately informing
274 players that they will be playing a whole match. Where possible, practitioners might also
275 consider providing players with regular information on how far away they are from being
276 interchanged to allow an end-spurt in exercise intensity to occur. Interestingly, if increased
277 exercise intensity in a single bout is desirable, this can potentially be achieved by telling the
278 athlete they are exercising for a shorter duration. However, this is likely to have implications
279 for any subsequent exercise bout if they are to be repeatedly interchanged.

280

281 The present study did not include an analysis of participants' contact intensity, which is likely
282 to have important implications for pacing during rugby league matches¹⁶. As such, future
283 studies may wish to examine the influence of knowledge of task end-point on individuals
284 pacing of contact intensity in addition to energy expenditure associated with running.
285 Furthermore, the implications of knowledge of task end-point on pacing during repeated
286 training sessions warrants attention, as this study would indicate that intensity - and therefore
287 potential training stimulus - can be altered based on an individual's understanding of the
288 exercise duration.

289

290 Conclusions

291 This study has demonstrated that knowledge of task end-point influences performance,
292 pacing and physiological and perceptual responses to simulated rugby league match-play. To
293 ensure an optimal pacing strategy, players should be accurately informed of their likely
294 exercise duration.

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303 **Conflict of Interest:** None.

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375

376 **Figure Legends**

377 **Figure 1.** Total (a) and high intensity (b) distance over the whole RLMSP-i
378

379 **Figure 2.** Changes in (a) distance covered, (b) High intensity distance, and (c) Peak speed
380 during the RLMSP-i. Q = quartile for a given bout. ▲ Denotes a meaningful difference
381 between CON and UN. ○ Denotes a meaningful difference between CON and DEC.
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Table 1. Physiological and perceptual measurements throughout the RLMSP-i during different trials. Data are mean \pm SD.

		Bout 1				Bout 2			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Heart Rate (b·min ⁻¹)	CON	159 \pm 24	167 \pm 23	169 \pm 21	167 \pm 22	160 \pm 23	166 \pm 21	166 \pm 21	167 \pm 22
	UN	158 \pm 11	166 \pm 11	166 \pm 11	165 \pm 12	159 \pm 10	164 \pm 12	163 \pm 12	162 \pm 13*
	DEC	162 \pm 15	171 \pm 12	171 \pm 12	172 \pm 12*	160 \pm 11	166 \pm 12	167 \pm 13	167 \pm 12
RPE (6-20)	CON	12.5 \pm 1.2	14 \pm 1.8	14.7 \pm 1.5	15.4 \pm 1.6	12.9 \pm 1.4	13.8 \pm 1.5	14.6 \pm 1.8	15.3 \pm 1.6
	UN	11.8 \pm 1.6 [#]	13 \pm 1.7 [#]	13.8 \pm 1.8 [#]	14.1 \pm 1.5 [#]	12.3 \pm 1.2*	13.2 \pm 1.7*	13.7 \pm 1.8 [#]	14 \pm 1.5 [#]
	DEC	12.6 \pm 1.6	14 \pm 1.2	15.1 \pm 1.6*	16.2 \pm 1.6*	12.8 \pm 2.1	14.1 \pm 2*	14.7 \pm 1.6	14.7 \pm 1.8*
Blood Lactate (mmol·l ⁻¹)	CON	3 \pm 1.6	-	-	4.7 \pm 3.2	-	-	-	5.6 \pm 3.9
	UN	2.6 \pm 0.8	-	-	2.9 \pm 1.3 [#]	-	-	-	2.8 \pm 1.7 [#]
	DEC	2.7 \pm 1	-	-	5.7 \pm 2.6*	-	-	-	3 \pm 1.8 [#]

Q= bout quartile. CON = control trial, UN = unknown duration trial and DEC = deception trial. * possible difference to CON, [#] likely difference to CON. All effects were *small*, with the exception of post measurements of blood lactate compared to CON, which were *moderate*.

Table 2. Changes in isokinetic peak torque at 60 deg·s⁻¹ in the knee extensors

	Pre	Post
CON (N·m)	239.3 \pm 48.6	224.2 \pm 50.7*
UN (N·m)	236.3 \pm 49.8	235.2 \pm 51.9
DEC (N·m)	236.9 \pm 37.2	225.6 \pm 40.4 [#]

* possible *small* difference to Pre. [#] likely *small* difference to Pre.



